SURVEY OF ALGAE ASSOCIATED WITH DEEPWATER RICE IN BANGLADESH

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ABSTRACT. — A detailed survey of the algae associated with deep water rice was undertaken in 1978 and the main results are described in this paper. Although essentially a qualitative survey, some data were collected on the density of the most abundant forms found growing at water depths of 32 to 169 cm. A total of 25 culm samples were taken in the principal depp water rice area on the floodplains of the three major river system of Bangladesh: 8 samples on the Gange floodplain, 7 on the Meghna floodplain and 10 on the Jamuna floodplain.

RÉSUMÉ. — En 1978 a été entreprise une étude des algues associées avec le riz d'eau profonde et les principaux résultats sont exposés ici. Bien que cette étude soit essentiellement qualitative, des données ont cependant été réunies sur la densité des espèces les plus abondantes trouvées à des profondeurs comprises entre 32 et 169 cm. 25 séries d'échantillons ont été récoltées sur le chaume des riz dans les principales zones de riz profond des plaines alluviales des trois grandes rivières du Bengladesh: 8 dans la plaine du Gange, 7 de la Meghna et 10 de la Jamuna.

INTRODUCTION

The importance of the algal community in the fertility of rice paddy soils is well documented, the contribution of nitrogen-fixing blue green algae being particularly significant (WATANABE & YAMAMOTO, 1971; VENKATARAMAN, 1972; MARTINEZ et al., 1979). Besides direct fixation by algae, nitrogen also reaches the plant via microbial decomposition on the death of the algal community (ROGER & REYNAUD, 1979).

BRAMMER (1976) remarked on the fertility of the deepwater rice (DWR) areas of Bangladesh. Receiving little fertilizer or manure and being largely

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flooded with clear water, DWR nonetheless shows a striking growth response every year following flood inundation. He attributed the major part of this fertility to the possible presence of blue-green algae (BGA). The first algae were actually identified from DWR in 1977 when two culm samples yielded 24 species. These included 12 BGA, 5 of them nitrogen-fixing species (MARTINEZ & CATLING, 1978).

Deepwater rice

DWR is grown in the valleys and deltas of Southeast Asia where floodwaters rise to depths of 1 to 4 metres. This ancient agro-ecosystem has produced a large diversity of plant types and many hundreds if landraces have developed. On the 1.6 million hectares of DWR in Bangladesh mean water depths of 1.5 to 1.7 metres were recorded for 1977-1979 (CATLING et al., 1980). Planting, mainly by broadcasting, takes place from March to May after the first good rains. The crop grows under rainfed conditions for the first 6 to 8 weeks until flood inundation in June. Maximum flood depths occur in August or September and floodwater recedes during October. Harvesting takes place from the end of October to early December after the water has drained away from most fields.

Fig. 1. — A typical deepwater rice of Bangladesh: variety Chota Bawalia. a: an entire plant in mid September at the end of the elongation stage; floodwater receding; b: fully developed nodal root system.

The DWR plant produces basal tillers during the preflood period. Flooding induces culm elongation which usually ensures that the shoot terminals remain above the floodwater surface but some Bangladesh varieties may have to survive a week's complete submergence. During the protracted culm elongation phase extensive root system develop from the submerged nodes, and nodal tillers are produced as a response to low culm density and insect damage (Fig. 1).

METHODS

Field sampling

Sampling began shortly after flood inundation in June and continued through the culm elongation and nodal tillering phase (July to mid September) to the heading or ripening stage in mid October. Samples were taken at water depths of 32 to 169 cm (mean of 91 cm). A total of 25 culm samples were taken in the principal DWR areas on the floodplains of the three major river systems of Bangladesh: 8 samples on the Ganges floodplain, 7 on the Meghna floodplain and 10 on the Jamuna floodplain (Fig. 2).

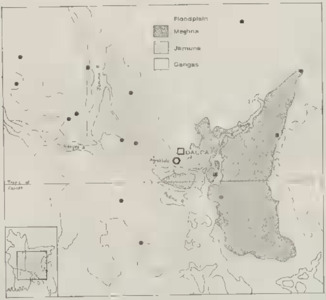

Fig. 2. — The three main floodplains of Bangladesh where most deepwater rice is grown with locations where samples were taken during the survey for algae.

The Jamuna series included 6 sequential culm samples from a typical farmer's field at Agrakhola (Dacca District), variety Chota Bawalia. The field was planted in mid April; flood inundation occurred on 18 June; maximum water depth was reached on 22 August and the floods receded on 15 October. No fertilizer was applied and very small amounts of alluvium are present in the floodwater. A winter leguminous crop is grown every year. The first sample was taken on June 23 (water depth 50 cm) and the last on 29 October (no flooding).

On each occasion a composite sample was made up consisting of 20 to 30 submerged culm sections 10 to 14cm in length which included a node with roots and often an undisturbed section of leaf sheath. Where the water depth exceeded one metre culm sections were taken at three points: near base of the plant, near the middle and just below the water surface. The freshly prepared sample was preserved in standard F.A.A. solution and sent to the Philippines for identification.

A smaller series of eight water samples were taken at the Agrakhola site, mainly for collecting planktonic algae. Six samples of water 10cm above the field bottom and two samples of algal blooms near the surface were taken into a 3 litre glass container. The organisms and detritus were allowed to settle out and were then preserved in Lugol's iodine solution.

Identification

Small sections were taken from nodal roots, culms and leaf sheaths and temporary mounts prepared in glycerine jelly or lactophenol blue for identification. In the case of the water samples, the residue was shaken up and two drops placed in a standard heamacytometer for examination as described by MARTINEZ et al. (1975). Algal concentrations were expressed as units/ml, a unit consisting of a colony, a filament or a single cell. Permanent mounts were deposited in the Herbarium of the College of Agriculture, University of the Philippines, Los Banos (CAHP).

The algae were identified to genus and species or to genus only. It was not possible to identify all forms to species level due to the great diversity and large bulk of the collected material, and the inherent taxonomic difficulties of some groups.

RESULTS

Checklists and the frequency of occurence for all identified species are given in Tables 2, 4, 5 and 6. For those genera with more than one species, the percentage occurence in the samples is first given for the genus as a whole, followed by the frequency for the individual species. A total of 139 species of algae were identified: 50 Bacillariophyta, 49 Chlorophyta, 6 Euglenophyta and a single Pyrrophyta (Table 1). No differences were noted in the incidence of algae between floodplains; all the more abundant forms in each group were present in all areas.

Because many algal units of epiphytic forms became dislodged from the substrate during the handling of the samples, habitat records are restricted to some of the more abundant forms.

Cyanophyta (blue-green algae)

Thirty-three species of blue-green algae (BGA) belonging to 22 genera were identified from DWR (Tables 1, 2). They comprised 24% of all algal forms taken in the survey; only five species were recorded in the four October samples (Table 1). BGA were particularly abundant on the culms (32 species) and were present in every culm sample up to October. In the frequency of occurence in the samples and the numbers of species recorded the most abundant genera on the culms were *Anabaena, Gloeotrichia, Oscillatoria, Nostoc, Carococcus* and *Lyngbya*. Fourteen genera were rare. *Gloeotrichia* spp. and *Lyngbya* sp. were epiphytic on nodal roots and leaf sheaths, sometimes in very large numbers, while *Anabaena* spp. and *Plectonema* sp. were epiphytic mainly on the leaf sheaths. Another 10 form were recorded less frequently on nodal roots and leaf sheaths (Table 2).

BGA were considerably less common in the water samples where only 7 genera and 11 species were represented (Table 2): *Oscillatoria* and *Gloeotrichia* occured most frequently. In the quantitative assessments at Agrakhola, very high concentrations of *Nostoc linckia* were evident in early July (water depth 64 cm) and *Oscillatoria subtilissima* produced a small peak in early September (Table 3).

Five of the most abundant genera recorded on the culms, and to a lesser extent in the water, (*Anabaena, Gloeotrichia, Oscillatoria, Nostoc* and *Lyngbya*, are capable of nitrogen-fixation (Table 2). *Anabaena* spp., *Gloeotrichia* spp., including two important forms recorded in the water samples: *G. echinulata* (J.E. Smith) Richter and *G. echinulata berhampurse* Rao C.B.), *Oscillatoria* spp. and *Nostoc linckia* (see above) were the dominant forms. Three of the rarer genera are also nitrogen-fixers. The BGA were quick to colonize flooded DWR. At Agrakhola dense colonies of *Anabaena* were visible on submerged culms six days after the arrival of floodwater. Less than two weeks later, 21 species were present (Table 1) which included most of the nitrogen-fixing forms. The five BGA which persisted into October were all nitrogen-fixers.

Chlorophyta (green algae)

Forty-nine species belonging to 33 genera were identified (Tables 1, 4), Chlorophyta comprising 35% of the algal species identified. As with the BGA, there was a decline in activity in October (Table 1). The culm samples yielded the highest numbers and variety of species. Genera occuring most frequently in the samples and represented by three or more species were *Oedogonium, Cosmarium, Tetraedron*, while *Chlorella, Scenedesmus, Staurastrum* and *Spirogyra* were fairly common. More than twenty forms were rarely taken on the culm. Large numbers of *Oedogonium* spp. were epiphytic on nodal roots and leaf sheaths but were absent from the water samples. *Cosmarium, Spirogyra* and four other forms were epiphytic on nodal roots.

Only 7 genera and 11 species were recorded from the water samples. *Ulothrix* and *Tetraedron* were the most abundant genera and large numbers of *Ulothrix chaetales* occurred in July at Agrakhola (Table 3).

Chlorophyta rapidly colonized flooded DWR; at least six species were recorded a week after flood inundation at Agrakhola.

Bacillariophyta (diatoms)

The surveys yielded 50 species of diatoms belonging to 25 genera (Tables 1, 5). More species were identified in the early part of the season than any of the other algal groups and they became completely dominant in October comptising 25 of the 37 identified species (Table 1). Genera recorded most commonly on the culm samples were *Coscinodiscus*, *Fragilaria*, *Nitzschia*, *Navicula* and *Synedra*. Some forms were apparently epiphytic on the leaf sheaths.

But the greatest numbers and variety of this largely planktonic group were recorded in the water samples. In the quantitative assessments of algae in the floodwater at Agrakhola (Table 3), 24 diatom species were present in significant concentrations compared with only two species for the other groups. *Cyclotella kuntzia* was most consistently present in significant numbers with a peak in July, while *Synedra ulna danica* occured from July to October and peaked in early September. Other species present in high concentrations in October were *Nitzschia palea*, *Fragilaria crotonensis* and *Navicula accomoda*. Genera occuring with a frequency of 50% or more included *Nitzschia*, *Cyclotella*, *Melosira*, *Navicula*, *Synedra*, *Fragilaria*, *Gomphonema*, *Pinnularia* and *Rhopalodia*.

Euglenophyta and *Pyrrophyta*

Six species of Euglenophyta were recorded (Table 6). *Trachelomonas* spp. were wall tepresented in the culm and water samples and small numbers of two species were recorded at Agrakhola in August and October (Table 3). All other Euglenophyta, and a single species belonging to the Pyrrophyta, were rare.

DISCUSSION

The study described here is believed to be the first systematic survey of algae associated with DWR in the Southeast Asian region. The survey revealed a rich variety of forms comprising 139 species belonging to 84 genera. Many species were undoubtedly missed during field sampling or overlooked when extracting from the samples for microscopic examination. Moreover, the taxonomy of the algae, especially the BGA, present serious problems due to the existence of considerable morphological variation. Thus the complex of algae is greater than that reported in this study as certainly many of the less abundant species were overlooked.

Many species were recorded in high densities as epiphytes on submerged nodal roots and culms or as largely planktonic forms in large concentrations in the water. As such algae are clearly important producers in the DWR ecosystem. They are consumed by a variety of «grazers» including aquatic insects, crustacea, snails (CATLING, 1980), and fish.

DWR farmers use small quantities of nitrogenous fertilizer and manure (CATLING et al., 1980) and because silt deposition is limited, at least on the Ganges and Meghna floodplains, only small amounts of plant food is derived from the weathering of silt (BRAMMER, 1976). The concentration of dissolved salts is floodwater is probably low or negligible. Thus the fertility of DWR must be explained in terms of biological sources of nutrition. In some areas nitrogen is produced by leguminous crops in the winter off-season for DWR. Much of the early season nutritional requirements of DWR are probably met from the accumulation of detritus and previous crop residues which are decomposed by soil microbes. Algal blooms certainly contribute much to this detritus.

Another important source of fertility is nitrogen-fixation by epiphytic BGA. In a recent paper KULASOORIYA et al. (1980), working in open tanks in the Philippines, found a high rate of nitrogen fixation by *Nostoc*, *Anabaena*, *Calothrix* and *Gloeotrichia* on submerged, decaying tissues of DWR. This amounted to 10-20 kg N/ha/crop. In the Bangladesh study, out of the five abundant nitrogen-fixing BGA recorded, four were present in large numbers on nodal roots and leaf sheaths. Three of the predominant genera were common to both studies. Besides nitrogen-fixation the BGA are also believed to supply growth substances to higher plants, including rice (VENKATARAMAN, 1972).

Algae were quick to colonize DWR, particularly the BGA and Chlorophyta; some forms were noticeable on the culms within a few days of flood inundation. Highest densities of epiphytic forms and of algal blooms were most evident from July to the end of September. With the exception of the diatoms, the numbers and variety of algae declined markedly with flood recession in October when the water in the fields becomes cloudy, malodorous and anaerobic. During that period the diatom were predominant in numbers and made up 68% of the identified species.

Deepwater rice, probably more than paddy rice, provides a favourable environment for the activity of algae for the following reasons : 1) It has a long growth period - 180 to 200 days - and is deeply flooded for 3 1/2 months. 2) A large biomass of plant material is produced which provides many niches fot epiphytic algae. Great BGA activity takes place on the long sections of floating culms present after the elongation phase (KULASOORIYA et al, 1980). 3) Organic matter is produced from the decay of submerged leaves and damaged culms. 4) On most floodplains clearwater flooding is usual and the water remains well-oxygenated until October. 5) Water temperature and light intensity are favourable as both are moderated by cloud cover and the floating DWR canopy. At Agrakhola an average temperature of 31°C (SD 1,8) was recorded 5 cm below the surface from June to October. This is near to the optimum for BGA (ROGER & REYNAUD, 1979). 6) The 4 to 5 month off-season for DWR is favourable for algal perennation as in many areas the soils remain moist below a mulch of straw and winter crops and in some places winter rice is grown under irrigation. In most years the rains begin again in March. No data are available on the pH levels or concentration of dissolved salts in the floodwater. Pesticides, which can either stimulate or inhibit algal activity (KAR & SINGH, 1978) are used very little in DWR (CATLING et al., 1980) and would in any case be mainly restricted to the pre- and postflood periods.

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Table 1. — Total numbers of algal species identified from flooded deepwater rice fields, Bangladesh, 1978.

Group	Total species identified		
	23 jun.-7 jul. (7 samples	oct. (4 samples	23 jun.-29 oct. (33 samples)
Cyanophyta	21	5	33
Chlorophyta	22	5	49
Bacillariophyta	30	25	50
Euglenophyta	6	2	6
Pyrrophyta			1
Totals	79	37	139

Table 2. – Cyanophyta (blue-green algae) identified from submerged culms and water in deepwater rice fields, Bangladesh, 1978.

Species	Nitrogen fixing	Epiphytic on deepwater rice		Occurence (%)	
		nodal roots	leaf sheath	culm samples	water samples
Anabaena spp.	+	+		84	13
A. oscillarioides	+			4	
A. planctonica			+	4	
A. sphaerica	+	+	++	4	
Anacystis sp.		+		4	
Aphanothece sp.				4	
Aulosira sp		+		4	
Borzia trilocularis				8	
Chamaesiphon sp		+		4	13
Chroococcus spp			+	32	
C. dispersus				4	
C. pallidus				4	
Cylindrospermum stagnale				4	
C. spp.	+			12	
Dactylococcopsis smithii				4	
Fremyella tenera				4	
Gloeotrichia spp.	+	+++	++	40	25
G. echinulata (2 varieties)	+				25
G. natans			++	8	
Lyngbya sp.	+	+++	++	20	13
Merismopedia sp.				4	
Microchaete tenera	+			12	
M. spp.			+	16	
Nostoc spp.	+	+	+	24	13
N. commune				4	
N. linckia	+				13
Oscillatoria spp.	+			40	50
O. formosa				4	
O. limosa				4	
O. subtilissima					50
O. tenuis				4	
Phormidium retzii	+				13
Plectonema sp.			++	4	
Scytonema sp.		+		8	
Synechocystis sp.				8	
Synechococcus aeruginosus				4	
Xenococcus sp.				4	

Table 3. — Algal concentrations of abundant species in the water from a deepwater rice field at Agrakhola, Bangladesh, July to october, 1978; samples taken 10-20 cm above bottom.

Species	Algal units per ml					
	Jul.		Aug.	Sept.	Oct.	
	3	21	11	2	21	29
Cyanophyta						
Nostoc linckia	9.800					
Oscillatoria subtilissima			300	1.300		
Chlorophyta						
Ulothrix chaetales		16.800				
Ulothrix sp.		200		200		
Bacillariophyta						
Coscinodiscus radiatus philippensis		200				
Coscinodiscus sp.					50	
Cyclotella kutzingia	200	1.000	50	300	200	200
Cymbella sp			50			
Epithemia gibberula					200	
Fragilaria brevistriata	700					
F. crotonensis					2.000	
Fragilaria sp			200			
Gomphonema lanceolatum				1.000		500
G. olivaceum					50	
Gomphonema sp.		200				
Gyrosigma acuminatum					50	
Melosira crotonensis		500			50	1.000
Navicula accomoda					1.700	200
N. dicephala		200				
N. divergens				200		
Navicula sp.			50			
Nitzschia palea	200				3.000	
Nitzschia sp.			100			
Pinnularia globiceps		200				
Pinnularia sp.					200	
Pleurosigma delicatum					200	
Rhopalodia gibba			50	200		
Synedra ulna danica		700	200	1.700	700	
Euglenophyta						
Trachelomonas crebea					200	200
T. volvocina			50			

Table 4. — Chlorophyta (green algae) identified from submerged culms and water in deep-water rice fields, Bangladesh, 1978.

Species	Epiphytic on deepwater rice: nodal roots	Epiphytic on deepwater rice: leaf sheath	Occurence (%): culm samples	Occurence (%): water samples
Ankistrodesmus falcatus			4	
Bulbochaete sp.	+	+	12	
Chaetosphaeridium globosum			4	
Chlorella sp.			40	13
Chlorellidiopsis sp.			4	
Chlorococcum sp.			8	
Cladophora sp	+		4	
Closterium spp.			12	
C. acerosum			4	
C. lanceolatum			4	
Coelastrum spp.			8	
C. microporum			4	
Coleochaete sp.	+		4	
Cosmarium spp.	+	+	72	13
C. contractum			4	
C. holmiense			4	
C. nitidulum				13
Cosmocladium pulchellum			4	
Crucigenia quadrata				13
C. tetrapedia			8	
Desmidium grevilii			4	
Euastrum sp.			4	
Euastropis sp.			8	
Gloeocystis ampha			4	
Micrasterias radiata			4	
Mycanthococcus antarticus			4	
Oedogonium spp.	++	+	92	
O. latioscutum	+		4	
O. oblongum	+		4	
O. spurium	+		8	
Oocystis spp.			8	
O. pusilla			4	
Pediastrum duplex			4	
Planktosphaeria gelatinosa			4	
Pleurotaenium truncata	+	+	8	
Protococcus sp.			4	
Rhizoclonium sp.			4	
Scenedesmus spp.			28	13
S. abundans				13
S. armatus			4	
Schroederia sp.			4	
Spirogyra spp.	+		20	13
S. daedaleoides			4	
Spondylosicum sp.			4	
Staurastrum spp.			24	
S. gracile			8	
Tetraedron spp.			48	25
T. asymetricum			4	
T. limneticum				13
T. minimum			28	
T. muticum			16	
T. trigonum			12	
Ulothrix spp.			12	50
U. chaetales				13

Table 5. – Bacillariophyta (golden algae) identified from submerged culms and water in deepwater rice fields, Bangladesh, 1978.

Species	Epiphytic on deepwater rice *	Occurrence (%) culm samples	water samples
Actinocylus spp		8	
A. niagarae		4	
Caloneis sp.		8	
Coscinodiscus spp.	+ *ls*	84	38
C. lacustris		4	
C. lineatus			13
C. pulchellum		4	
C. radiatus philippensis			13
Cyclotella spp.		28	88
C. kutzingia			75
Cymbella spp.		16	25
C. amphicephala			13
C. cistula		16	13
Diatoma anceps		4	
Epichrysis paludosa		4	
Epithemia spp		4	13
E. gibberula			13
Eunotia sp.	+ *ls*	8	
Fragilaria spp.	+ *ls, nr*	80	63
F. brevistriata	+ *nr*	12	25
F. construens		4	
F. crotonensis		4	25
F. rhomboides		36	
F. tenuicollis		4	13
Gomphonema spp.	+ *ls*	36	63
G. herculeana		4	
G. olivaceum	+	16	13
G. lanceolatum	+		25
G. sphaerophorum		4	
Gyrosigma spp.		8	13
G. acuminatum			13
Licmophora ehrenbergii		4	
Melosira spp.	+ *ls*	36	75
M. crotonensis	+ *ls*	4	50
M granulata			13
Navicula spp.	+ *ls*	52	75
N. accomoda			63
N. dicephala			25
N. divergens			13
N. exigua			13
Neidium sp.			13
Nitzschia spp.		72	100
N. linearis			13
N. palea		4	50

N. sigma		4	
Pinnularia spp.		12	63
P. acrosphaeria		4	
P. globiceps	+ ls	4	50
Pleurosigma spp.			13
P. delicatum			13
Rhoicosphenia curvata		8	
Rhopalodia spp.		24	50
R. gibba		16	50
R. gibberula		4	
Surirella robusta		4	
Synedra spp		48	75
S. ulna danica		20	63
Tabellaria fenestra		4	
Thallasiothrix frauenfeldii		4	

* ls: leaf sheath; nr: nodal roots.

Table 6. — Euglenophyta and Pyrrophyta identified from submerged culms and water in deepwater rice fields, Bangladesh, 1978.

Species	Occurr. in culm samples (%)	Occurr. in water samples (%)
Euglenophyta		
Euglena sp.	8	
Phacus spp.	8	
P. acuminatus	4	
Trachelomonas spp.	44	63
T. crebea	4	38
T. hispida		13
T. volvocina		25
Pyrrophyta		
Glenodinium pulvisculus	4	

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